Weddell Sea Moorings

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1. PROJECT SUMMARY

The world's deep oceans are filled with water masses formed at the continental margins of Antarctica. The Weddell Sea is a major source of these so-called Antarctic Deep and Bottom Waters. Relatively warm, saline Circumpolar Deep Water (CDW) enters the Weddell Gyre to the east of the Greenwich Meridian. As it traverses the gyre, it feeds bottom water-forming processes on the continental shelves, and interacts with floating ice shelves to produce a variety of Weddell Deep and Bottom water types.

This project maintains three deep and bottom water focused moorings south of the South Orkney Islands in the Northwest Weddell Sea to provide a time series of the combined outflow (currents and temperature/salinity) of Antarctic Deep and Bottom Water drawn from various sites within the Weddell Sea. The moorings were initially installed and maintained as part of the NOAA-funded Consortium on Oceans Role in Climate: AbRupt climate CHangE Studies (CORC-ARCHES) Southern Ocean Modern Observations program.

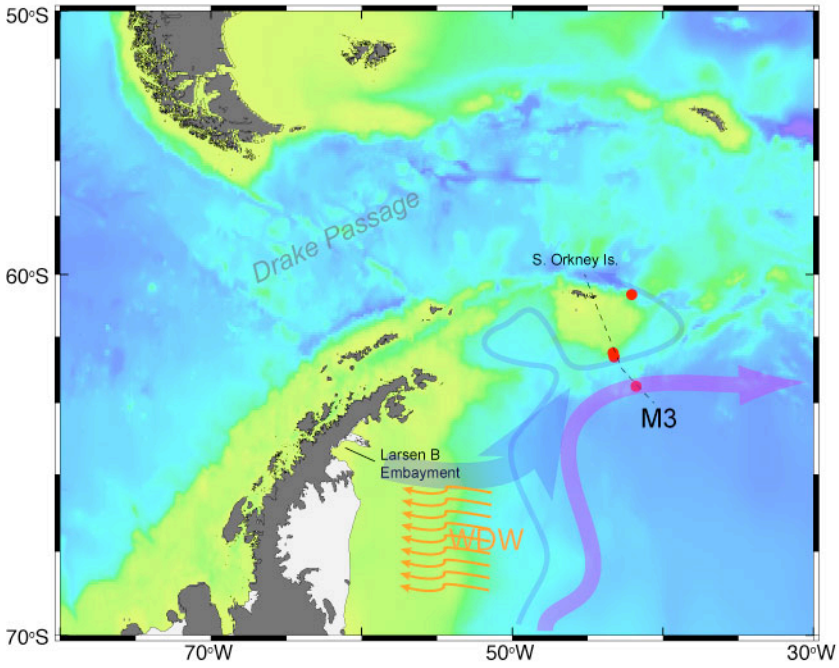

Figure 1. Location of the Weddell Sea moorings (red dots) and repeat CTD/Tracer line (dashed line). Shown schematically are the pathways of deep and bottom waters formed by interaction of WDW with continental and ice shelf waters.

First installed in April 1999, the moorings have been serviced using ship time made available by other programs, primarily through the National Science Foundation Office of Polar Programs (OPP), and principal investigators funded by OPP who graciously allow our team to sail on their

cruises. As time and resources allow during the mooring maintenance cruises, oceanographic stations to collect profiles of conductivity, temperature and tracers (CTD/tracer) are occupied at the mooring sites and at stations distributed along a line between the mooring locations (Figure 1). The cost of ship time devoted to the mooring work and associated CTD/tracer stations, typically 3 to 5 days, has been supported by funding from OCO.

More recently, ship time arrangements have been made with colleagues at the British Antarctic Survey (BAS), governed by an Agreement of Cooperation between LDEO and BAS. The agreement with BAS provides for sharing of equipment, personnel and data between LDEO and BAS to allow the mooring sites to be serviced at nominally two-year intervals, with BAS providing the ship time to do so. Our collaboration with BAS will continue, so this work is part of an international effort.

The most recent rotation of the moorings was achieved from the BAS vessel RRS Ernest Shackleton in February-March 2007. The newest of the ARCHES moorings, M_4, within the trough feeding Weddell water into the Scotia Sea is now part of an enhanced array of moorings in the trough, using LDEO and BAS equipment to better resolve this branch of bottom water spreading.

We now have time series of currents, temperature and salinity of the outflow of dense water from the Weddell Sea spanning 8 years at M_3 (Figure 2), which is positioned within the primary pathway of outflow of dense Weddell water, and 6 years at M_2. The M_2 gap of 2005 and 2006 was due to lack of ship time to re-deploy M_2 after recovery in March 2005, but it has now been reinstalled in March 2007.

The time series reveals significant seasonal and interannual variability in the outflow of dense Weddell Sea water. An annual pulse of the coldest bottom water at the mooring site is evident in the May-July time frame, which suggests (from the mean bottom speed) export of shelf water into the deep ocean at the upstream bottom water formation sites in the Dec-Feb period, i.e. austral summer (a rather unexpected discovery). However, the exact timing of the outflow events and their temperature and salinity characteristics vary from year to year.

The extended time series will contribute to an understanding the processes that control the transport and characteristics of the bottom waters that emanate from the Weddell Sea, as required to better assess the reaction of the Southern Ocean meridional overturning circulation and associated deep ocean ventilation to a warming climate. Research questions that could be pursued with the extended Weddell Sea time series include: are there any ‘environmental’ conditions, e.g. wind, sea ice, Larsen Ice shelf break-up, or climate oscillations such as the Antarctic Dipole, Southern Annular Mode, that can account for the seasonal and interannual fluctuations observed in the bottom flow passing the Weddell Mooring sites? How does the observed behavior of the Weddell MOC compare to model output? How might the Weddell Sea MOC change with climate warming?

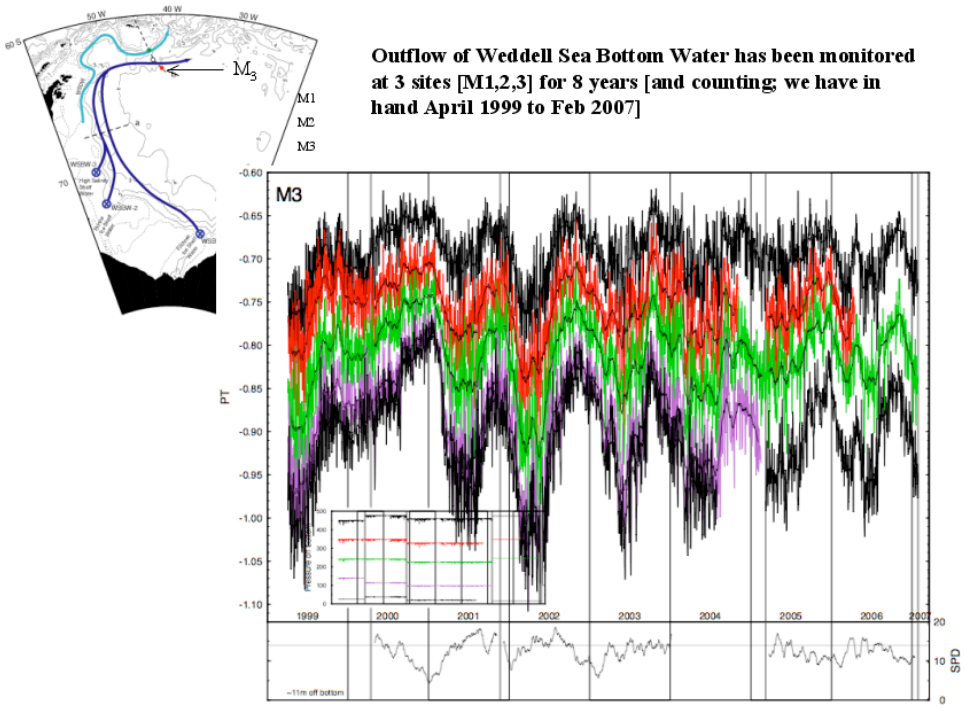

Figure 2. M3 temperature and bottom speed time series.

2. ACCOMPLISHMENTS

The performance period covered by this report is 1 July 2008 – 30 September 2008; no OCO funding was received in FY2007. To date, we have completed all preparations for a cruise on RRS Ernest Shackleton, to be carried out under a cooperative arrangement with colleagues at the British Antarctic Survey (BAS) to continue servicing the Weddell moorings, and to expand the array in conjunction with the BAS and other IPY programs in the region (Figure 3). The configuration of the joint LDEO-BAS array of moorings is shown in Figure 4.

Data are archived and made available as they are recovered from the moorings at the project web site: http://www.ldeo.columbia.edu/res/div/ocp/projects/corc.shtml
This web site will be upgraded during the next year.

A preliminary analysis of the time-series data collected to date will be presented at the 2008 Fall AGU meeting:

Eight Year time series of the outflow of Weddell Sea Bottom water
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We present a nearly 8 year record (April 1999 to February 2007) of the currents and thermohaline stratification within the lower ~500 m of the water column at a mooring (M3) at 4565 m depth, south of the South Orkney Islands, positioned within the outflow of dense Weddell AABW. The time series reveals significant seasonal and interannual variability. A pulse

of the coldest bottom water is evident in the May-July period, though the precise timing and duration varies with year. Intensification of the near bottom stratification is observed as the bottom water attains its coldest values. The coldest bottom events occurred in 1999 and 2002, while in 2000 it was absent. At bottom temperatures <-0.8°C the salinity fluctuations produce a 'fan-like' appearance in T/S space suggesting a varied source of dense shelf water. The coldest bottom water <-1.0°C is relatively salty indicating a source in the southwest Weddell Sea, about 1300 km along isobaths to the mooring site. The typical bottom speed at M3 of 10-15 cm/sec implies a shelf water export time during the austral summer. A record at a second mooring (M2) at 3059 m depth displays a much reduced annual cycle, but it too records a relatively warm period in 2000. Correlations of the M3 time series with NINO3.4 and SAM suggest that these indices lead M3 on the order of 14-20 months, implying a likely relationship between the water mass and surface forcing. Both M3 and M2 were reinstalled in March 2007.

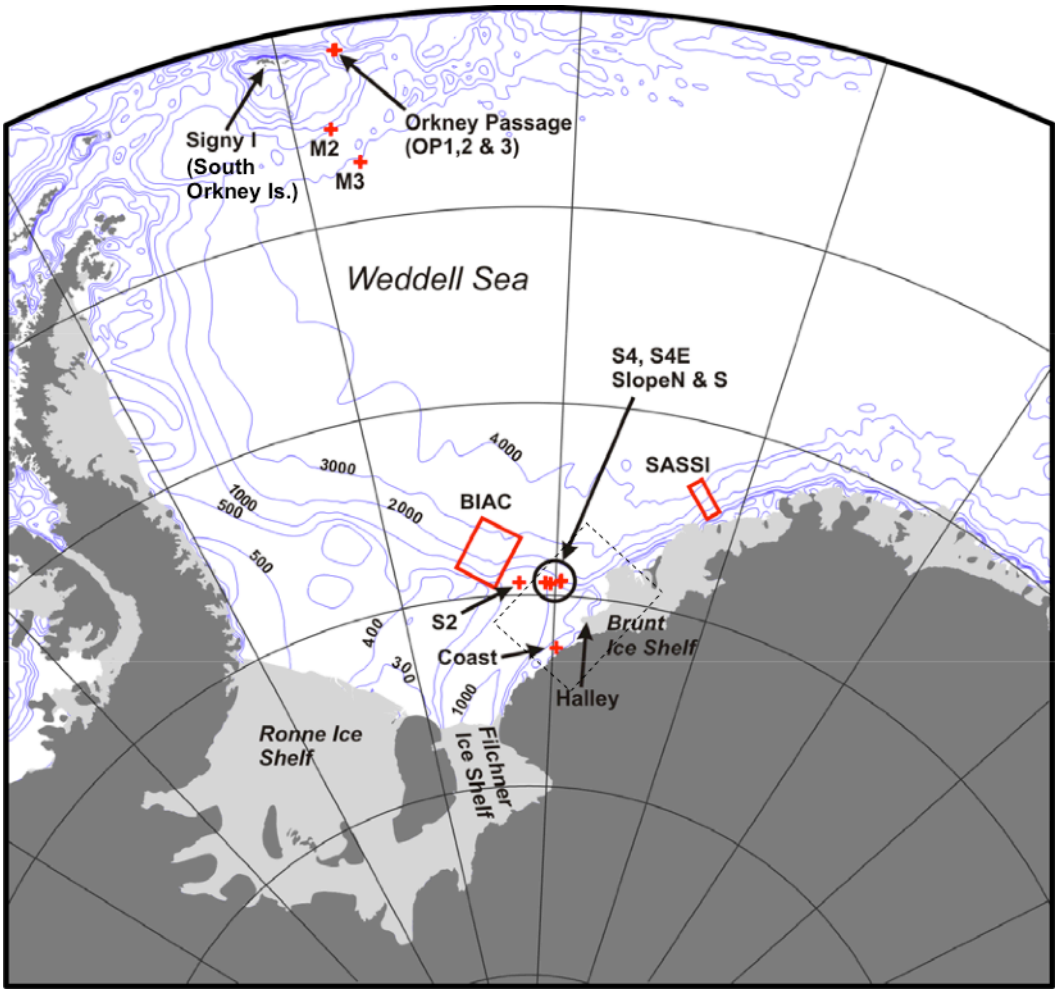

Figure 3. Planned mooring recovery/redeployment activities during RRS Ernest Shackleton cruise scheduled for Jan-Mar 2009.

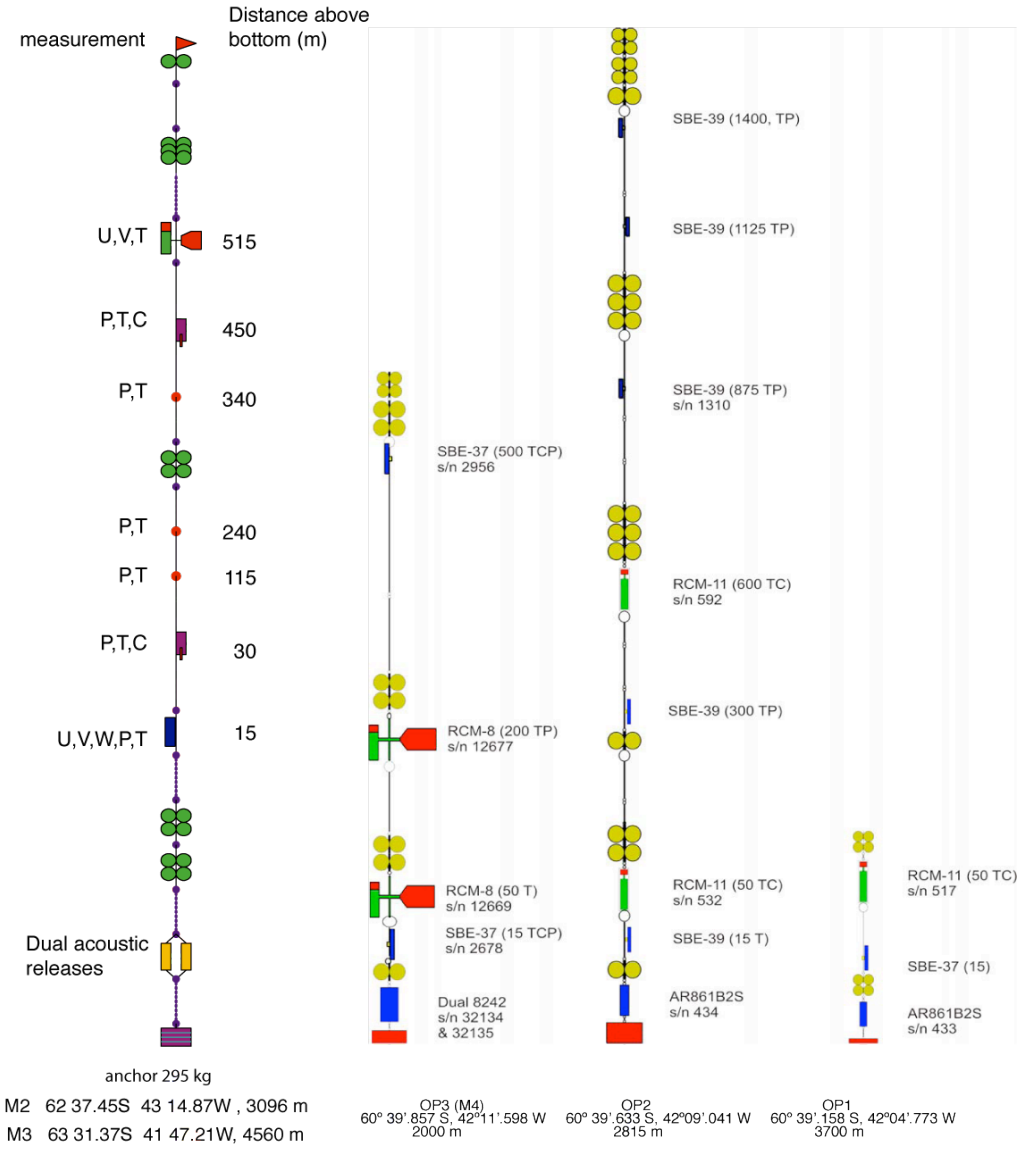

Figure 4. Weddell mooring configurations and positions. RCM current meters will gradually be replaced with acoustic current meters. Additionally, new temperature and temperature/salinity recorders are purchased in off-field years and phased into the mooring array to allow for return and recalibration of older units.